CATEGORY 1

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MARCHI,M.L. Washington Public Power Supply System
RECIP.NAME RECIPIENT AFFILIATION

SUBJECT: LER 96-006-01:on 961018,discovered intergranular attack & intergranular stress corrosion cracking of tubes in both SGs.Caused by destructive exam of tubes pulled from KNPP SGs.Plugged & repaired defective tubes.W/970630 ltr.

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NRC-97-66

June 30, 1997

10 CFR 50.73

U. S. Nuclear Regulatory Commission
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Ladies/Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Reportable Occurrence 96-006-01

In accordance with the requirements of 10 CFR 50.73, "Licensee Event Report System," the attached Licensee Event Report (LER) for reportable occurrence 96-006-01 is being submitted.

Sincerely,

M. L. Marchi
Manager - Nuclear Business Group

SLB/jmf

Attach.

cc - INPO Records Center
US NRC Senior Resident Inspector
US NRC, Region III

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NRC FORM 366 (4-95) U.S. NUCLEAR REGULATORY COMMISSION

APPROVED BY OMB NO. 3150-0104
EXPIRES 04/30/98

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS MANDATORY INFORMATION COLLECTION REQUEST: 50.0 HRS. REPORTED LESSONS LEARNED ARE INCORPORATED INTO THE LICENSING PROCESS AND FED BACK TO INDUSTRY. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (T-6 F33), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

LICENSEE EVENT REPORT (LER)

(See reverse for required number of digits/characters for each block)

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TITLE (4) Intergranular Attack & Intergranular Stress Corrosion Cracking of Tubes in Both Steam Generators Results in Category C-3

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
10	18	96	96	-- 006 --	01	06	30	97	N/A	05000
									FACILITY NAME	DOCKET NUMBER
										05000

OPERATING MODE (9)	N
POWER LEVEL (10)	94

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more) (11)

20.2201(b)	20.2203(a)(2)(v)	50.73(a)(2)(i)	50.73(a)(2)(viii)
20.2203(a)(1)	20.2203(a)(3)(i)	X 50.73(a)(2)(ii)	50.73(a)(2)(x)
20.2203(a)(2)(i)	20.2203(a)(3)(ii)	50.73(a)(2)(iii)	73.71
20.2203(a)(2)(ii)	20.2203(a)(4)	50.73(a)(2)(iv)	X OTHER
20.2203(a)(2)(iii)	50.36(c)(1)	50.73(a)(2)(v)	Specify in Abstract below or in NRC Form 366A
20.2203(a)(2)(iv)	50.36(c)(2)	50.73(a)(2)(vii)	TS 4.2.b.7.c

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
SL Bernhoft	(414) 433-1416

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS		CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS
B	AB	SG	W120	Y						

SUPPLEMENTAL REPORT EXPECTED (14)			EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
YES (If yes, complete EXPECTED SUBMISSION DATE).	X	NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

On October 18, 1996, with the plant in a refueling shutdown, the in-service inspection of steam generator (SG) tubes was completed for the 1996 refueling outage. Due to the significant number of indications detected in the Westinghouse hybrid expansion joint (HEJ) sleeved tubes, extensive tube repairs were required. The tube repairs and plugging were completed on May 31, 1997. As required by KNPP's Technical Specifications and 10 CFR 50.73, this LER provides a written 30-day report to the NRC on the results of the in-service inspection, and number of tubes plugged and repaired.

The mode of tube degradation occurring in the hot leg tubesheet crevice region and hot leg and cold leg tube support plate crevice region is outside diameter intergranular attack and stress corrosion cracking. The mode of degradation occurring in the HEJ sleeved tubes is primary water SCC and is due to residual stresses from the sleeve installation. In accordance with KNPP TS's, all defective tubes were plugged or repaired. This increased the overall equivalent plugging percentage from 21.32 percent to 26.07 percent for the 1997 to 1998 operating cycle.

Secondary side chemistry additions will continue during the 1997 and 1998 operating cycle to reduce the caustic environment and corrosion/erosion of the secondary side components.

Description of Event

On October 18, 1996, with the plant in a refueling shutdown, the in-service inspection of steam generator [SG] tubes [TBG] was completed for the 1996 refueling outage. The results of the in-service inspection were reported to the NRC in Licensee Event Report (LER) 96-006-00, on November 15, 1996. Due to the number of parent tube indications (PTIs) detected in Westinghouse hybrid expansion joint (HEJ) sleeved tubes, extensive tube repairs were required. The HEJ sleeved tube repairs, tube sleeving and tube plugging were completed on May 31, 1997. The purpose of this report is to update LER 96-006-00 to include the number of tubes which were repaired or plugged. This is in accordance with the requirements Kewaunee Technical Specifications (TS) 4.2.b.7.a and TS 4.2.b.7.c.

The Kewaunee Nuclear Power Plant (KNPP) SGs are Westinghouse model 51. The tubes are constructed of mill-annealed inconel 600 and are partially rolled for a length of 1.5 to 2.5 inches into the tubesheet. As a result of tube degradation, significant plugging and sleeving efforts have been required in each SG. Prior to the 1996 refueling outage, SG A contained 771 plugged tubes and 1702 sleeved tubes (1690 Westinghouse HEJ sleeves and 12 Combustion Engineering welded sleeves). SG B contained 518 plugged tubes and 1870 sleeved tubes (1866 Westinghouse mechanical sleeves and 4 Combustion Engineering welded sleeves). The combined equivalent plugging percentage for the two SGs was 21.32 percent.

The planned KNPP 1996 SG eddy current examination program for each SG was:

1. A 100% bobbin coil examination through the entire length of all tubes not previously plugged or sleeved.
2. A 100% bobbin coil examination of all sleeved tubes from the top of the sleeve around the U-bend to the end of the tube.
3. Rotating probe examination of all open row 1 and row 2 U-bends and 20% of the row 3 U-bends.

4. Rotating probe examination of 100% of the inservice sleeve upper expansion joints.
5. Rotating probe examination of 100% of the hot leg crevice region.

Based on the above listed examination scope, KNPP TS 4.2.b.2.a requirements were satisfied.

There are three areas in the KNPP SGs in which active modes of degradation were detected as a result of the 1996 tube inspection. These are:

1. Axial outside diameter stress corrosion cracking (ODSCC) occurring within the hot leg tubesheet crevice region,
2. Axial ODSCC and intergranular attack occurring within the hot leg and cold leg tube support plate intersections, and
3. Primary water stress corrosion cracking (PWSCC) occurring in the upper joint of Westinghouse HEJ sleeved tubes.

The eddy current examination of the hot leg tubesheet crevice region in SG A (915 tubes) found 11 tubes which were classified as defective (Single Axial Indications (SAI) or Multiple Axial Indications (MAI)). Since greater than 1% of the examined tubes were considered defective (categorized as C-3), the Nuclear Regulatory Commission (NRC) was notified at 0946 hours on October 18, 1996, as required by KNPP TS 4.2.b.7.c and 10 CFR 50.72(b)(2)(I). The eddy current examinations of the hot leg tubesheet crevice region in SG B (1000 tubes) found 4 tubes which were classified as defective (SAI or MAI). No circumferential crack-like indications were detected within the tubesheet or top of the tubesheet. Prior to the 1996 refueling outage, a F*/EF* tubesheet alternate repair criteria was approved for use (TS 4.2.b.6); however it was not implemented. All of the tubesheet defective tubes were either plugged or repaired by sleeving with CE TIG welded sleeves.

The tube support plate intersections were inspected and dispositioned in accordance with the requirements of TS 4.2.b.5 (i.e., using a 2 volt alternate repair criteria (ARC) for indications attributable to ODSCC within the tube support plate intersections). The eddy current examination of the tube support plate intersections found 0 tubes with indications in SG A, and 5 tubes with indications in SG B that did not satisfy the 2-volt ARC. These indications were removed from service by tube plugging. No circumferential crack-like indications were detected within the tube support plate intersections. To support the industry database for the ARC, one tube containing two tube support intersections with indications was removed from SG B for structural testing and destructive analysis.

During the 1996 inspection, the plus point probe was used to inspect the upper and lower hybrid expansion joint (HEJs) of the Westinghouse sleeves, and the weld zone region for the in-service CE TIG welded sleeves. One CE TIG welded sleeve was confirmed to have a weld zone indication (WZI); this tube was plugged. The remaining 15 CE TIG welded sleeves had no reported WZIs and were left inservice.

The eddy current examination results of the sleeve upper HEJs in SG A (1690) tubes found 907 tubes (53.7%) with circumferential indications in the parent tube at the lower transition of the upper roll expansion within the pressure boundary defined in TS 4.2.b.4.b (termed PTIs). The eddy current examination results of the sleeve upper HEJs in SG B (1866 tubes) found 587 (31.5%) with circumferential indications in the parent tube at the lower transition of the upper roll expansion within the pressure boundary defined in TS 4.2.b.4.b. TS 4.2.b.4.b defines the pressure boundary for parent tube indications within the HEJ region in terms of a diameter difference between the sleeve hardroll peak diameter and the diameter at the elevation of the parent tube indication. As these indications are within the pressure boundary, they were classified as defective. Since greater than 1% of the examined tubes were considered defective (categorized as C-3), the NRC was notified at 1625 hours on October 7, 1996, as required by KNPP TS 4.2.b.7.c and 10 CFR 50.72(b)(2)(I).

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TEXT *(If more space is required, use additional copies of NRC Form 366A)* **(17)**

Due to the number of indications detected in the Westinghouse HEJ upper joints, seven sleeve/tube sections were removed for structural and leakage testing, and extensive tube repairs were required. The initial HEJ sleeved tube repair method was to place a laser weld in the center of the existing upper hardroll. This repair effort was performed during November and December of 1996. During the hardroll welding effort a number of difficulties were encountered resulting in a very low weld acceptance rate. Following extensive testing, the welding procedure was revised and the weld location moved to the upper hydraulic expansion region. The initial weld acceptance rate was much higher; however a significant number of the welds failed after application of the post-weld stress relief step. This weld failure was reported to the NRC in LER 97-002-00. Detailed information on the laser weld repair process has been discussed with the NRC staff in meetings on October 10, 1996; December 17, 1996; January 14, 1997; March 24, 1997; and April 14, 1997. A proposed TS amendment request to allow the laser weld repair process was submitted on September 6, 1996, and revised on April 22, 1997 and May 15, 1997. TS amendment 135 was approved for use in the KNPP SGs on June 7, 1997.

Due to the number of unsuccessful laser weld repairs, additional HEJ sleeved tube repairs were required prior to placing the SGs back in service. The method used to repair the sleeved tube was to remove the lower portion of the existing sleeve, expand the upper remaining HEJ, and installing a longer replacement sleeve. The repair process, termed re-sleeving, was discussed with the NRC in meetings on March 24, 1997 and April 21, 1997. A proposed TS amendment request to allow the re-sleeving was submitted on April 24, 1997. TS amendment 134 was approved for use in the KNPP SGs on June 7, 1997.

The overall examination results for 1996 outage found 923 tubes (35.27 percent of tubes inspected) in SG A, and 598 tubes (20.84 percent of tubes inspected) in SG B, which met the KNPP definition of defective. According to the KNPP TS 4.2.b.7.a, following each in-service inspection, the number of tubes which require plugging or repairing shall be reported to the Nuclear Regulatory Commission (NRC) within 30 days. The C-3 category requires:

1. Prompt notification of the NRC (TS 4.2.b.7.c).
2. A written follow-up to the NRC (TS 4.2.b.7.c).
3. Plugging or repair of all defective tubes (Table TS 4.2-2).
4. An examination of additional tubes in the affected areas if the sample size is less than 100 percent in the affected area (Table TS 4.2-2).
5. Increasing the required SG inspection frequency to once per twenty months (TS 4.2.b.3.b).

This LER satisfies the 30 day reporting requirements of KNPP TS 4.2.b.7.a and 4.2.b.7.c. All tubes classified as defective were either plugged or repaired. The defective non-sleeved tubes were repaired using a CE TIG welded sleeve; the defective HEJ sleeved tubes were repaired with either a laser welded repair or re-sleeving.

The table below provides a summary of the plugging and repairs performed as a result of 1996-1997 SG tube activities:

Area	NUMBER OF TUBES REPAIRED DURING 1996/1997 OUTAGE							
	Steam Generator A				Steam Generator B			
	Plugged	Sleeved	LWR	Re-sleeved	Plugged	Sleeved	LWR	Re-sleeved
Low Row U-Bends	2	-	-	-	0	-	-	-
Tube Support Plate Intersections	0	-	-	-	5	-	-	-
Hot Leg Tubesheet Crevice (Recovery)	1	47	-	-	0	0	-	-
Hot Leg Tubesheet Crevice (Inservice) (1)	20	15	-	-	18	0	-	-
ABB TIG Sleeve Joint	1	-	-	-	0	-	-	-
HEJ Sleeve Joint (Recovery)	97	-	133	120	75	-	94	0
HEJ Sleeve Joint (Inservice)	365	-	248	246	348	-	198	0
Total for Outage	485 (2)	62	381	366	371	0	292	0
Cumulative Total	839	922 (3)	381	366	785	1333 (4)	292	0
% Equivalent Tubes Plugged	26.89%				25.25%			

Note: At the start of the outage plugs were removed from 550 previously plugged HEJ sleeved tubes. The number of repairs is based on a population of 1201 HEJ sleeved tubes in SGA, and 706 HEJ sleeved tubes in SG B with PTIs. The number of HEJs plugged also includes the pulled HEJ sleeved tubes.

(1) Includes those initially repaired using elevated rerolling repair technique.
(2) Does not included recovery populations.
(3) Includes 850 Westinghouse HEJ sleeves and 72 ABB TIG welded sleeves.
(4) Includes 1329 Westmghouse HEJ sleeves and 4 ABB TIG welded sleeves.

Cause of Event

The tube wall degradation occurring in the hot leg tubesheet crevice region and tube support plate intersections is primarily due to outside diameter intergranular attack and outside diameter stress corrosion cracking (IGA/SCC). This conclusion is based on destructive examination of tubes pulled from the KNPP SGs during the 1990, 1993 and 1996 refueling outages, eddy current signals, and industry experience with similar SGs. Outside diameter IGA/SCC is typically associated with a restricted geometry; e.g., crevice region, and with a caustic environment, i.e., a pH greater than ten.

The HEJ sleeved tube parent tube degradation, primary water stress corrosion cracking (PWSCC), is due to the residual stresses imparted on the parent tube during the HEJ sleeve installation process. This conclusion is based on destructive examination performed on three HEJ tube specimens removed from the KNPP SGs during the 1995 outage, and engineering analysis.

Due to the significant number of HEJ sleeved tubes reported with PTIs during the 1996 inservice inspection, extensive sleeve repairs were required. The first attempt to repair the tubes was to place a weld in the center of the existing upper hardroll. This effort had a very low success rate due to the initiation of hot cracks in the welds caused by multiple re-weld passes performed at the same location. The weld location was relocated to the upper hydraulic expansion area. Initially, there was a very high success rate; however, several of the welds failed after application of the post-weld stress relief step. The weld failure was due to uneven stress distribution across the weld during the stress relief process causing mechanical shearing of the weld. Detailed information on the laser weld repair process, and subsequent weld failures has previously been reported to the NRC.

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Analysis of Event

This report is being submitted in accordance with TS 4.2.b.7.a which requires a report to be submitted to the NRC within thirty days of completing the inservice inspection and plugging of the SGs.

The current equivalent plugging percentage increased from 24.94 percent to 26.89 percent in SG A, and from 17.69 percent to 25.25 percent in SG B. Since these percentages exceeded KNPP's Updated Safety Analysis Report (USAR), which assumed an acceptable plugging limit of 25 percent per SG, the safety analysis was revised. The new analysis assumes an acceptable plugging limit of 30 percent for full power operation. The current level of plugging percentages remains acceptable within the revised limits. To support the increase in SG plugging and the associated change in reactor coolant system flow, additional analyses were performed to ensure a minimum departure from Nucleate Boiling Ratio (DNBR) of 1.30 is maintained in the core at all times, as required by TS 3.10.n. Therefore, continued operation of the plant with an overall equivalent plugging level of 26.07 percent was determined to be safe and not an unreviewed safety question.

Corrective Actions

In accordance with KNPP's TS, all tubes classified as defective were plugged or repaired.

Sludge lancing was conducted during the 1996 refueling outage to reduce the amount of sludge and to remove contaminants from the tubesheet. A secondary side boric acid addition program continues to be implemented to reduce the caustic environment in the tube crevices and prevent tube support plate denting. The program includes boric acid soaks at low power levels and on line boric acid addition at normal power levels. Evidence indicates that boric acid may reduce the crack growth rate. Also, a secondary side alternative amine addition program continues to be implemented. Amine addition minimizes the corrosion/erosion in the two-phase steam piping. Sludge (corrosion product) transport into the steam generators is thereby minimized and results in a decreased sludge pile.

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A molar ratio control program is also used at KNPP. This is accomplished by adding ammonium chloride to the secondary side to control the molar ratio. This is designed to maintain a neutral pH in the tubesheet crevice environment.

Additional Information

Equipment Failure: Westinghouse Model 51 steam generator tubes. The tubing is mill annealed Inconel 600.

Similar Events:

1. LER 95-001, Intergranular Attack and Intergranular Stress Corrosion Cracking Of Tubes In Both Steam Generator Results In Category C-3.
2. LER 94-004, Intergranular Attack and Intergranular Stress Corrosion Cracking Result In Defective Steam Generator Tubes.
3. LER 93-004, Intergranular Attack and Intergranular Stress Corrosion Cracking Results in Both Steam Generators Being Categorized as C-2.
4. LER 92-006, Intergranular Attack and Intergranular Stress Corrosion Cracking Results in Both Steam Generators Being Categorized as C-3.
5. LER 91-005, Intergranular Attack and Intergranular Stress Corrosion Cracking Results in Both Steam Generators Being Categorized as C-3.
6. LER 90-005, Intergranular Attack and Intergranular Stress Corrosion Cracking Result in Defective Steam Generator Tubes.
7. LER 89-007, Intergranular Attack and Intergranular Stress Corrosion Cracking Result in Defective Steam Generator Tubes.

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8. LER 88-003, Intergranular Attack and Intergranular Stress Corrosion Cracking Result in Defective Steam Generator Tubes.
9. Letter from D.C. Hintz (WPSC) to G.E. Lear (NRC) dated April 23, 1986.
10. LER 85-06, Steam Generator Tube Plugged in Incorrect Location.
11. Letter from C.W. Giesler (WPSC) to S.A. Varga (NRC) dated May 1, 1984.